THE APPLICATION OF OPERATIONS RESEARCH TECHNIQUES TO THE EVALUATION OF MILITARY MANAGEMENT INFORMATION SYSTEMS

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THESIS

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ABSTRACT

To date, little progress has been made toward the establishment of scientific procedures by which a military manager can evaluate complex cybernetic systems such as management information systems.

To provide a methodology yielding quantitative results which may assist a commander and his staff in this analysis, it is proposed that management information systems be evaluated as a whole by a technique defined as the semantic differential. Each characteristic of the system evaluated is compared to a standard or reference characteristic desired in a well designed system and a value is assigned based on the closeness of the comparison.

A second, more detailed, approach is also considered. This technique detects redundancy and lack of responsiveness in a system by means of a matrix model of the system. Using input-output analysis on the model, it is possible to determine excessive routing of information and lack of the necessary information to compute decision rules.

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I. INTRODUCTION

A. BACKGROUND AND PURPOSE

Every military resource manager is a decision maker and a problem solver. For example, the squad leader is faced with the task of managing his men, their equipment, and available time in a mission oriented environment. The description of the task confronting a commanding general of an army is similar; the only difference being that of proportion. Each of these men accomplishes his task in generally the same manner. Each gathers data, converts the data into meaningful information, and then uses the information to make decisions.

In an organization with a hierarchal structure such as the Army, information plays a second and equally important role. Each manager at every level of command is required to collect certain items of information and report these items to higher levels of command. This information is then used by the managers at these higher levels of command to make their decisions.

If the systems used by the managers at each echelon of command to gather and analyze information are not adequate, there is a high probability that the information used will be inaccurate, incomplete and/or irrelevant. In this case, not only does the performance of the manager suffer, but also higher levels of command receive "bad" information which can and usually does result in untimely or incorrect

management decisions. This frequently leads to the imposition of management information and data requirements on lower levels that are far in excess of what can reasonably be useful to higher echelon management. Managers, therefore, continually strive to improve their means of gathering data, of molding it into useful information, and of analyzing this information to suit their needs.

The problem confronting managers, and the problem this paper attacks is "how can a complex system such as a management information system (MIS), with as many definitions as there are systems, be analyzed and evaluated?" "Is there a methodology for evaluating an existing management information system?" "If someone should design a MIS for the Army which they claim is better than any existing MIS, how can this be verified?"

The problem of analyzing and evaluating a MIS is extremely difficult. A few important factors contribute to this. First of all, when one considers a large complex system such as a MIS for a private industry or a logistical MIS for the Army, one must deal in the abstract. This is due to the fact that it is impossible to accurately define the components of the system, it is difficult to measure how the system will function in a given environment, and the human factor's influence on the overall operation of the system is not readily measureable. Secondly, the characteristics of a MIS that may be rated as excellent for one organization may prove ineffective for another. This is because a MIS must be tailored to meet the demands of its user.

Hence, it is necessary to describe the characteristics of a MIS in the most general terms, as the reader will soon discover. The last obstacle to analyzing a MIS is that there does not seem to exist a set of standards against which to measure a particular MIS. Due to the abstract nature of the system, quantifiable measures are not readily identifiable.

This thesis represents a beginning step toward satisfying a need in the Army today. There has been a great deal of research conducted in the areas of information theory and evaluation techniques, but almost all effort has been directed toward such technical subjects as file organization, storage and retrieval procedures, coding and decoding, and transmitting procedures. If the reader is interested in the more technical aspects of information systems evaluation, he is referred to Refs. 2, 7, 9, 11, 15, 18, 40, 48, 56, 62, and 69. A critical review of the literature has not revealed very many techniques that a middle or high level manager or military commander can use to evaluate the MIS he is currently using or a proposed MIS intended to replace it. In short, the military manager has been left to use his intuition and past experience (some refer to this as military judgement) to satisfy his needs in this area. This paper presents two operations research techniques that he can use to scientifically evaluate a complex system such as a MIS and suggests that many more procedures exist.

B. DEFINITION OF TERMS

1. Management Information System

The introduction of the computer as an important tool of management caused emphasis to be placed on the deliberate design and implementation of information systems. It seems strange that to date, there does not exist a generally agreed upon definition of a management information system. This fact adds to the problem of evaluating such a system for it is extremely difficult to evaluate an ill-defined subject. The term, management information system, has been used to describe a multitude of electronic data processing equipment or devices, data collection systems, and even clerical arrangements. This paper will not use the term in these contexts.

This paper will use the term as it is defined by the Office of the Chief of Staff, U. S. Army:

> "Management Information System: An organized assemblage of resources and procedures required to collect, process, and disseminate data for the purpose of converting it to meaningful information for decision making in executing the command/ management functions of planning, organizing, directing, coordinating, and controlling the use of resources to accomplish missions and tasks." [Ref. 47]

Terms synonomous with MIS are, Management Control Systems, and Command and Control Systems. This paper will also use the term, system, to mean MIS.

2. Data

Data are facts or inputs to the system which can take on a variety of forms. They are the reports or image of the units and activities of the Army which are collected and stored. Data are the elements of which information is comprised. [Ref. 12]

3. Information

Information is the system output which results from the conversion of data into a product which enables a manager to take action within a given frame of reference. [Ref. 14]

4. Operations Research Technique

An operations research technique is a procedure which structures a real life situation into a quantitative model, abstracting the essential elements so that a solution relevant to the decision maker's objectives can be sought. The technique allows a scientific approach to decision making. [Ref. 33]

5. Decision Factor

A variable, the value of which, when compared against an arbitrary rule or standard, determines a solution relevant to the decision maker's objectives.

C. SCOPE

It is this author's contention that the techniques of operations research lend themselves to the analysis and evaluation of a management information system. It is further contended that there exists

relatively simple techniques that military managers, or any user of the system, could use without intensive special training.

This paper will discuss two general approaches to the problem of the analysis and evaluation of management information systems. The first approach is to consider the system as a whole, qualitatively evaluate it with respect to the characteristics of a well-designed MIS, and then convert these qualitative measurements to quantitative measurements in order to allow comparison with other systems. One advantage of this approach is that it identifies both the weak points and the strong points of the system. The manager can then retain the strong points while strengthening the weak points, thereby improving his system. Secondly, the approach is so simple that an untrained analyst can implement the approach.

The second approach would be used to amplify the results of the first more general approach. For example, if the first technique indicated redundancy in the system, the second technique could measure how much redundancy exists. The second approach uses the many operation research techniques available to measure specific aspects or characteristics of a system. This paper will consider in detail only one such technique, a technique which a manager could possibly use without the help of an operations research analyst. Other techniques will be mentioned and briefly discussed with relation to the evaluation of a MIS.

Both approaches will be applied in this paper to partially evaluate a MIS recommended by a civilian contractor to replace many of the systems now in use in the Army. This system, an integrated materiel readiness, supply and maintenance MIS, is currently awaiting implementation by the Army and is expected to replace three separate categories of management information systems.

It should be noted that the techniques discussed in this paper are not limited to the evaluation and analysis of a MIS at a certain level of management operating under a particular mode. The techniques are equally applicable to the logistics battalion utilizing a manual MIS as they are to a computerized Army-wide command information system.

II. THE SYSTEM APPROACH

A. GENERAL COMMENTS

This portion of the paper will present a technique for evaluating any complex system which does not lend itself to quantification. The technique was originally used to evaluate or measure in quantifiable terms what meaning a concept might have to a group of people. The reader, upon completion of this section, will probably recognize that the personnel efficiency report and several types of inspection worksheets use a similar technique. Management information systems can lend themselves readily to this type evaluation. If properly utilized, this procedure will enable any user of a MIS to evaluate his current system and a proposed replacement for it, and then compare the results.

The next section of the paper is comprised of a description of a technique called the semantic differential. Following this will be a discussion of the characteristics of a well-designed MIS. The last section of this portion of the paper will apply these characteristics to the semantic differential and will show the evaluation of a proposed MIS.

B. THE SEMANTIC DIFFERENTIAL

The semantic differential is a combination of controlled association and scaling procedures. The evaluator is provided with the characteristics of a well-designed system to be differentiated and a set of bipolar adjectival scales against which to do it. His only task is to indicate, for each item (pairing of a characteristic with a scale,) the direction of his association and its intensity on a n-step scale. [Ref. 30]

Figure 1 is an illustration of the semantic differential technique used to evaluate a complex system. Assume for illustrative purposes that a senior commander has asked ten of his staff officers and subordinate commanders to evaluate the system in question.

The choice of the characteristics used is entirely up to the manager and/or analyst conducting the survey. Obviously, the more a person knows about the system being evaluated, the more meaningful the characteristics will be, and the better the technique will work. The technique also permits the military manager to use military judgement factors and, in fact, encourages their use.

FIGURE 1.

An Example of the Semantic Differential Technique
Used to Evaluate a Complex System

Factor Weight	Characteristic of Well-designed System	+3	+2	+1	0	-1	-2	-3	Characteristic Poor Designed System
		Scale							
3	Characteristic 1.	//	////	/	/		/	/	Characteristic 1.
2	Characteristic 2.			~~////~~	//	//	/		Characteristic 2.
1	Characteristic 3.		/		//	///	~~////~~	/	Characteristic 3.
1	Characteristic 4.		///	/	/	///	//		Characteristic 4.
3	Characteristic 5.		//	/	///	//	//		Characteristic 5.

The factor weights are assigned by the manager based on his judgement of the relative importance of the characteristics listed with respect to his management objectives. In the example outlined in Figure 1, the manager believed that characteristics one and five were more important than the rest. This procedure is defensible in the absence of an external reliable criterion. [Ref. 30]

Once the decision maker has completed his survey, he can evaluate his system in two ways. First, each characteristic may be evaluated separately. In this manner, the strong and weak areas of the system can be identified. For example, in Figure 1, by adding up the checks for characteristic one, one can determine a rating of 10 which, on an ordinal scale, would indicate a strong point. Characteristic 3, on the other hand, has a rating of -14; obviously a weak point in the system that would require corrective action.

The second method assigns a scalar number to the entire information system. The procedure is as follows:

Let: R = system rating

$S_{(j)}$ = sum of column j, $j = 3, 2, 1, 0, -1, -2, -3$

W_i = factor weight for characteristic i, $i = 1, 2, \ldots, n$

N_{ij} = number of checks received by the j^{th} column of characteristic i.

The system rating, R, is then equal to sum of the column totals:

$$R = \sum_j S_{(j)},$$

where $S_{(j)} = j \sum_i N_{ij} W_i$, $\quad j = 3, 2, 1, 0, -1, -2, 3$

For the example in Figure 1:

$$S_{(+3)} = 3(2x3) = 18$$

$$S_{(+2)} = 2[(4x3) + (1x1) + (3x1) + (2x3)] = 44$$

$$S_{(+1)} = 1[(1x3) + (5x2) + (1x1) + (1x3)] = 17$$

$$S_{(0)} = 0$$

$$S_{(-1)} = -1[(2x2) + (3x1) + (3x1) + (2x3)] = -16$$

$$S_{(-2)} = -2[(1x3) + (1x2) + (5x1) + (2x3)] = -36$$

$$S_{(-3)} = -3[(1x3) + (1x1)] = -12$$

$$R = 18+44+17+0-16-36-12 = 15$$

The decision maker now knows that, based on the sample of the population which he surveyed, his MIS has a scalar rating of 15 which indicates only that the system appears to have more strong points than weak points. By comparing the score obtained by the system against the ratings of the other systems derived by the same raters, the manager can determine a relative overall effectiveness index of the system.

The scalar rating taken by itself may be misleading. For example, a system may have a large positive rating and still have one or more characteristics rated very low by the majority of raters. Thus, a system selected because of a high R rating may in fact be sorely lacking in a few important areas. Hence, the decision maker should also evaluate the ratings received by each separate characteristic. By doing so, he can identify specifically the strong and weak areas of his system.

Thus, the manager who considers the R value of the system together with the dispersion of evaluations for each characteristic will be able to determine the strong and weak points of a MIS and also compare it to other systems. Furthermore, by the identification of the weak points in his system, the manager can initiate the next step in the systems design cycle by taking necessary actions to correct those weak points.

In order to use the technique of the semantic differential it is necessary to determine the characteristics of a well designed MIS. The next section is an examination of these characteristics.

C. CHARACTERISTICS OF A WELL DESIGNED MANAGEMENT INFORMATION SYSTEM

1. General

The research by the author in this area was done by a critical review of books, journals, and technical reports relating to the design of management information systems. Every authority appeared to have his own ideas about what characteristics a MIS should have. The characteristics discussed here are those that are accepted by most and, in the author's opinion, are most applicable to the military organization. It should be noted that there are no rules or standards in existence which say that the characteristics discussed in this paper are "good" or all-inclusive. It is believed that this derived set of characteristics are most important in that they provide a framework for the evaluation of a system regardless of the evaluation technique

GENERAL	SPECIFIC
Data Base	a. Useful to all levels of management in the organization. b. Specialized data bases held to a minimum.
Information	a. Accurate. b. Complete and comprehensive. c. Available and relevant to all. d. Understandable, meaningful and readily usable. e. Timely. f. Compatible to all requirements. g. Information is of high quality.
Type of System	a. Justified by structure and requirements. b. Compatible with other systems.
Long-short Range Perspectives	a. Provides basis for decisions in policy and procedures. b. MIS measures over-all effectiveness. c. MIS establishes trends, permits management by exception.
Flexibility	a. Capable of being updated with minimum down-time and costs. b. Can adapt to changes in doctrine and operational reqmnts.
Responsiveness of the System	a. Responsive to the demands of the commander. b. Responsive to the needs of subordinates. c. Maximum automatic control is permitted. d. Each person given all information needed.
Capacity	a. Operates under maximum work load conditions. b. Information capacity of any channel is not exceeded.
Acceptability	a. All users accept system. b. System is simple and reliable.

TABLE I. Summary of MIS Characteristics

GENERAL	SPECIFIC
Redundancy	a. Data not reported by many channels. b. Direct channels of information flow.

TABLE I. (con't) Summary of MIS Characteristics

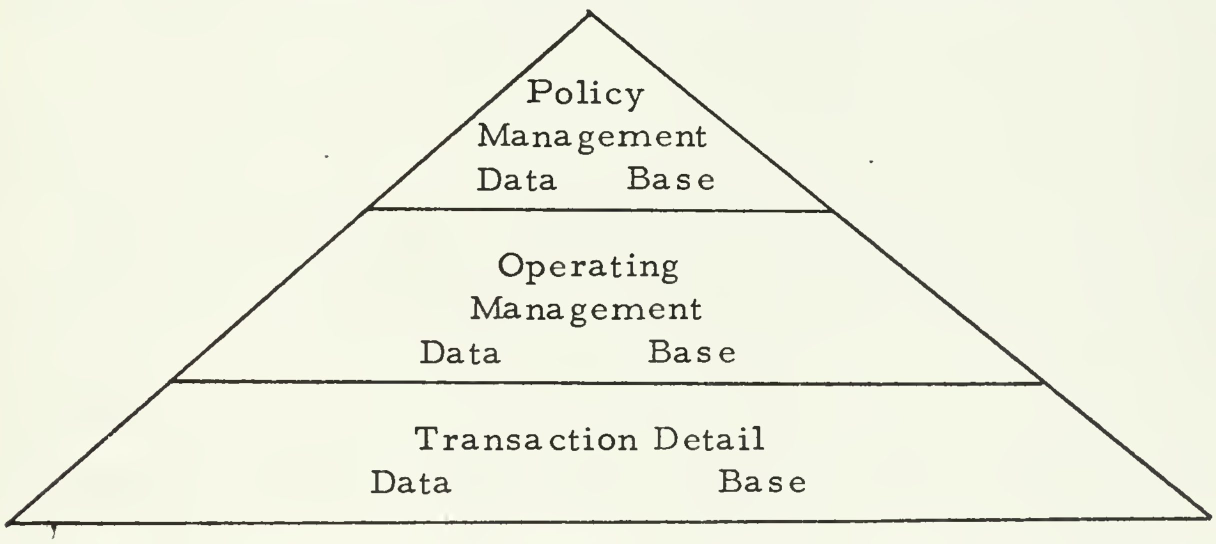
used. A summary of the characteristics to be discussed in this paper is listed in Table I.

2. Data Base Characteristics

A management hierarchy exists in the military with different information needs at its various levels. The question arises as to how many data bases are needed in the MIS to serve the various levels.

The bottom section of Figure 2 reflects all of the necessary details of each logistical operation in a military service. Operating management does not need all this detail, but it does need a subset of it, as indicated by the center section of Figure 2. At the top, policy management needs yet another subset of the overall data base. Can these varying needs be served by a single data base, or will it be necessary to structure three different data bases? [Ref. 31]

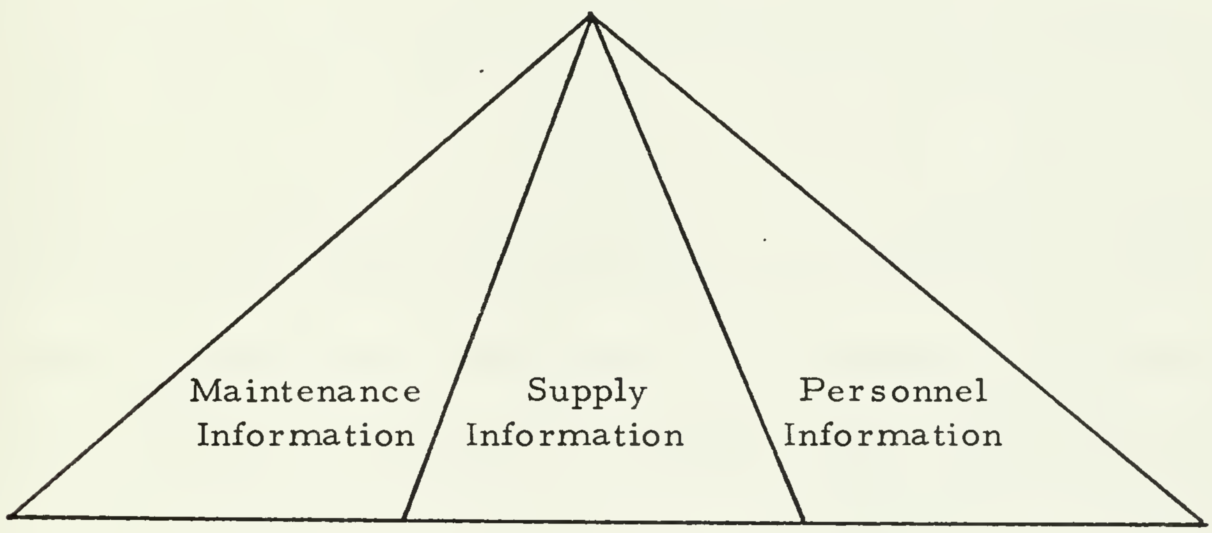
FIGURE 2. How Many Levels of Data Base? [Ref. 31]



A similar problem, but one having a vertical rather than a horizontal alignment, is shown in Figure 3. Can maintenance management use the same data base as the supply or personnel people, or is

each intent on having a data base of it's own? In the Army today, there is a tendency to follow the latter direction. A major challenge then to the designer of a MIS lies in trying to integrate a data base so that it can be useful to all organizational levels and components. The objective is neither centralization nor decentralization of management, but rather to provide a system that will accommodate either one.

FIGURE 3. How Many Specialized Data Bases? [Ref. 31]



There are opponents to the concept of complete data bases for integrated information systems. These people believe in the theory of the concept, but also believe that any attempt to design such a system is doomed to failure simply because of the varied and unpredictable nature of the data required for managerial planning. Since the data required depends upon the problem being studied and these problems cannot be foreseen, they feel the integrated system is hopeless.

Advocates of the integrated MIS hold the view that current data base design concepts which facilitate the retrieval of data elements in response to unstructured and non-predetermined management requests contribute significantly to the realization of the integrated system. These people believe that non-integrated systems have many disadvantages. First, duplication of information coverage exists as each level and component uses and interprets information to suit their own needs. Secondly, a breakdown in communications is apt to occur as identical information is distorted by bias and conflict in the organization. [Ref. 19] Lastly, confusion tends to result as policy formulation and operating decisions are complicated by the need to evaluate conflicting information supplied by different data bases. [Ref. 5] In the final analysis, the degree of integration of the data base is a function of the costs involved to obtain this integration. Thus, although a completely integrated data base might be desired, the costs incurred may make a less integrated system more realistic. The current state of integrated data bases in the Army is well described in Refs. 6, 45-47.

In summary, one characteristic of a well designed MIS is that its data base be so structured that it is useful to all levels and components of an organization; the goal being a completely integrated data base. This characteristic easily lends itself to the semantic differential, particularly if all levels and components of an organization are represented in the evaluator's survey.

3. Information Characteristics

It can be argued that any MIS is only as good as the information that flows through it; hence, information must be evaluated. It is necessary, therefore, to determine a set of characteristics which may be applied to the semantic differential. One study interested in this area, Ref. 17, researched all available relevant books, reports, and papers and prepared a set of seven characteristics of information as listed below:

a. Accuracy (precision and validity)

b. Quantity (completeness, comprehensiveness, and predictability)

c. Relevance (pertinence)

d. Simplicity (understandable, meaningful, and readily usable)

e. Timeliness (accessability)

f. Compatibility (standardization)

g. Quality (value and worth)

It should be noted that each element in the set of information characteristics lends itself to detailed analysis by advanced operations research techniques. For example, a recent study by the Logistics Research Project of George Washington University attempted to relate the quantity of information submitted by Navy maintenance units to the accuracy of the data comprising that information. In this case, the volume of information could be measured, but its accuracy could not.

By utilizing standard multiple regression analysis, cluster analysis, and discriminant analysis techniques, it was shown, for particular Naval units, that there existed a positive relation between the volume of information submitted and the accuracy of the data reported. Hence, by measuring the quantity of information in the system, an analysis of the accuracy could be made. [Ref. 28] This example points out a use of the semantic differential not heretofore discussed. The items or characteristics making up the differential may be used as starting points for more advanced detailed analysis.

4. Type of System- Manual or Computer-based

The type and complexity of any management information system must be determined by the decision maker in terms of his own organizational requirements and structure. [Ref. 42] The Army Materiel Command, an agency responsible for most of the materiel in the Army, would find great difficulty in managing their assets if they were to rely on a manual system. On the other hand, an ammunition company commander utilizing a computer-based MIS for his internal management would probably tend to become so completely tied up in computer operations that he would neglect his primary duty of leadership to his men.

In addition to analyzing his organizational structure, the manager must also consider the information that is to be processed. For example, if he processes large amounts of information, has many repetitive operations, has a number of interacting variables, requires

accuracy and speed, then a computer could certainly be used to best advantage. [Ref. 21]

This characteristic is closely related to the cost of a computerized system at a given instant in time. An organization may well require a computer but not be able to afford one. However, should a break-through in computer technology occur which would reduce the costs to the user, the same organization might find it suddenly feasible to convert from a manual system to a computer-based system.

The manager must also look outward in determining the type of system he desires to use. This author is convinced that sometime in the relatively near future a worldwide military management information system will be utilized by all services. At present, most of the major service commands, the different unified and specified commands and their subordinate commands each have their own MIS. Each of these commands, while having different missions and objectives, have many common data bases and software requirements. Compatibility between the systems of the commands would permit a greater capability at a lower cost than would be possible if systems were totally different. Compatibility refers to the situation where the hardware and the software at one level in a hierarchy is able to work with the hardware and software at other levels. Thus, in determining what type of system to implement, the manager should always consider compatibility with the systems of his higher (and lower and equal) commands.

5. Long-range and Short-range Perspectives

In order to be effective as a timely and efficient management tool, a management information system must view organizational resources and functions from long-range and short-range perspectives. As a long-range management tool, it must provide a basis for decisions in the areas of policy, doctrine, and procedures. As a short-range tool, it must measure over-all effectiveness, be capable of establishing and displaying trends and provide means for the detection and avoidance of incipient problems by the technique of management by exception. [Ref. 4]

6. Responsiveness of the System

Any well designed MIS should be responsive to management. This means that the system must have the ability to process pertinent information at all levels of an organization and cause implementation of decisions in a timely manner. This timely information must be able to meet dynamic and fluid command and control requirements. [Ref. 5]

Responsiveness can be achieved in at least two ways. First, the system must be responsive to the demand of the commander. A system that has relevant and accurate information flowing in it is useless to the manager if he cannot receive this information before decisions are required. The importance of the system's ability to deliver the required information to the decision maker when he needs it cannot be understated.

Responsiveness also works in the opposite direction - from commander to subordinate. Once the commander receives the required

information and makes his decision, the system should be able to issue orders based on that decision to subordinates within a certain time; the time differing with different type decisions.

The MIS should be designed so as to permit maximum automatic management control. This implies relegating to machines all mechanical decisions, leaving for consideration only those problems requiring judgement and more difficult analysis. This type responsiveness would produce a more accurate, more consistent, and generally better work product. It would also permit more time for management to devote to exceptions, creative thinking, basic planning, and self-improvement. [Ref. 24]

7. Flexibility of the System

Flexibility is the ability of the system to adapt to unforeseen changes of a permanent nature in doctrine, policy, or operational requirements. A system should also be capable of evolutionary improvements by taking advantage of state-of-the-art advances as they occur and all experience gained from changing situations. [Ref. 17]

> All too often, though not universally, the manager is confronted with report formats that he may have agreed to, reluctantly, two or three years earlier. He has changed his requirements in evolutionary patterns and will continue to change as his grasp of the job improves or as the area he controls undergoes change. He cannot use what the computer now spews out in great quantity at frequent intervals, and his requests for different reports are met by shocked references to reprogramming costs or by promises that the changes can surely be made within the next year if all goes well. [Ref. 28]

Along the same line, a MIS designed for the U. S. Army Pacific Command, for example, should be capable of adapting to the various systems and doctrine passed down from the Department of the Army such as a change in the army maintenance records system.

8. Capacity

Capacity is a measure of the ability of a system to operate effectively under maximum workload conditions. Regardless of whether a MIS is manual or computer-based, if the capacity is exceeded, little opportunity will be available for study or analysis of information before decisions are made. Indeed, decisions may be made without supporting information. The non-technically qualified user of a system would probably find it difficult to accurately evaluate this characteristic. Using the Semantic Differential, he could only record his feelings, intuition, or judgement about capacity and this rating may in fact differ from the actual case. The decision maker could note however, how many people "felt" the capacity of a system was inadequate, for example, and investigate this characteristic more closely.

9. Acceptability

Acceptability is an extremely abstract characteristic of a MIS, yet it lends itself most readily to evaluation by means of the semantic differential. It is defined as a measure of a system's ability to develop a positive user's attitude toward the system and it's objectives. A system, in order to be effective, must be accepted by the people who use it. In the case of a new or proposed system which has yet to be

used, the differential would measure potential users' initial impressions of how effective they think the system will be, based on their interpretation of the system proposals.

The keynote to user acceptance and use is simplicity. The more rules and restrictions involved in system operation, the better the chance for error. A simple system will enhance the learning process and will make the overall operation more efficient.

Reliability is also a key factor in user acceptance. Unexpected or irregular performance must be held to a minimum. Many potential supporters of a system have been lost because of embarrassing and unexpected system performance. [Ref. 28]

10. Redundancy

Redundancy is an undesirable characteristic of a MIS in that it implies unnecessary duplication. It is important that the reader understand that some duplication may be necessary if, for example, the designer desired a cross check of data for error detection purposes. If redundance in data serves no purpose, it may result in a waste of man-hours throughout the organization served by the system. Furthermore, it tends to throw confusion into the act of decision making by presenting multiple interpretations of data, as the manager receives seemingly conflicting information.

Conflicting information is due to distortion or bias which appears as information is transmitted through an organization. Bias occurs as information is eliminated, modified, or added before a

message is relayed to the decision maker. [Ref. 2] Thus if identical data elements are originally reported by two sources, there results two possibly unequal interpretations of these data by the time they reach the decision maker.

The reader should note that bias in a system is inversely related to the degree of automatic decision making discussed previously. The more a system is automated, the less chance there is for bias to enter the system. It should also be noted, however, that even a fully automatic system may be redundant simply because of faulty design.

In summary, one means of minimizing bias and distortion is to minimize redundancy in the system. Another means is to make the channels of information flow more direct to the appropriate manager, i.e., make the system more automatic. Redundancy of a proposed MIS for the Army will be partially evaluated in the second portion of this thesis.

D. THE SEMANTIC DIFFERENTIAL USED TO EVALUATE A MIS

An example of a complete semantic differential that could be used to evaluate a MIS is shown in Figure 4. In this instance, factor weights have not been provided, therefore let $W_i = 1$, $i=1, 2, \ldots, n$. The characteristics discussed in the preceding section have been brought forward and have been applied to the semantic differential.

The reader should bear in mind that this is only an example. The evaluator determines exactly what characteristics of his system he

FIGURE 4.

Semantic Differential to Evaluate a Management Information System

Characteristic of a Well Designed MIS	+3	+2	+1	0	-1	-2	-3	Characteristic of a Poor Designed MIS
1. Data Base								1. Data Base
a.) Useful to all levels of mgmt in the organization	x							a.) Not useful to any level of mgmt in the organization
b.) Specialized data bases held to a minimum					x			b.) No attempt to limit specialized data bases
2. Information								2. Information
a.) Accurate				x				a.) Inaccurate
b.) Complete and Comprehensive.		x						b.) Incomplete and Incomprehensive.
c.) Available and relevant to each manager at each level.	x							c.) Unavailable & irrelevant to most mgrs at most levels.
c.) Understandable, meaningful and readily usable.		x						d.) Confusing, meaningless and wrong format.
e.) Timely			x					e.) Not timely, late
f.) Compatible to all requirements.	x							f.) Incompatible to most requirements.
g.) Information is of high quality.		x						g.) Information is of low quality.
3. Type of System								3. Type of System
a.) Justified by structure and requirements.	x							a.) Not justified by structure and requirements.
b.) Compatible with other systems	x							b.) Not compatible.

FIGURE 4. (continued)

Semantic Differential to Evaluate a Management Information System

Characteristic of a Well Designed MIS	+3	+2	+1	0	-1	-2	-3	Characteristic of a Poor Designed MIS
4. Long-short Range Perspectives								4. Long-short Range Perspectives
a.) Provides basis for decisions in policy and procedures.		x						a.) Little basis for decisions in policy and procedures.
b.) MIS measures over-all effectiveness.	x							b.) MIS failes to measure over-all effectiveness.
c.) MIS establishes trends, permits mgmt by exception			x					c.) Fails to show trends and allow for mgmt by exception.
5. Flexibility								5. Flexibility
a.) Capable of being up-dated with min down-time and cost						x		a.) Not capable of being up-dated at all.
b.) Can adapt to changes in doctrine and operational rqmts.		x						b.) Cannot adapt to changes in doctrine and requirements.
6. Responsiveness of the System								6. Responsiveness of the System
a.) Completely responsive to demands of the commander.			x					a.) Hardly responsive to the demands of the commander.
b.) Completely responsive to needs of subordinates.						x		b.) Hardly responsive to needs of subordinates.
c.) Maximum automatic control is permitted.			x					c.) Minimum automatic control is permitted.
d.) Each level and position given all information needed.		x						d.) Each level and position not given all information needed.

FIGURE 4. (continued)

Semantic Differential to Evaluate a Management Information System

Characteristic of a Well Designed MIS	+3	+2	+1	0	-1	-2	-3	Characteristic of a Poor Designed MIS
7. Capacity								7. Capacity
a.) Operates under maximum work load conditions.	x							a.) Fails under maximum work load conditions.
b.) Information capacity of any channel is not exceeded.	x							b.) Information capacity of most channels is exceeded.
8. Acceptability								8. Acceptability
a.) All users accept system.		x						a.) Few users accept system.
b.) Maximum number of users participated in design.		x						b.) Minimum number of users participated in design.
c.) System is simple.						x		c.) System is complicated.
d.) System is reliable.			x					d.) System is unreliable.
9. Redundancy								9. Redundancy
a.) Same data not reported by multiple reporting units.			x					a.) Same data reported by multiple reporting units.
b.) System has direct channels of information flow.		x						b.) System has indirect channels of information flow.

he desires to have evaluated. For a particular MIS, it is possible that the characteristics would be in much more detail than the general terms used in the example.

As is shown in Figure 4, the technique has been applied to evaluate a proposed MIS recommended by a civilian research company. The evaluation was accomplished by comparing the characteristics of the proposed MIS (as reported in the project paper) to the characteristics of a well designed MIS. By using an adequate sample of the population and other standard statistical procedures, an evaluation could determine the strong and weak points of a MIS and its relative standing to other management information systems. The technique also serves as the first step of a detailed analysis by breaking the large problem into a set of small, easier to handle, problems.

III. DETAILED ANALYSIS OF INFORMATION FLOW

A. GENERAL COMMENTS

The last section dealt with analysis of a MIS when considering the characteristics of the system as a whole. This section discusses a methodology of analyzing a specific characteristic of the system. Thus, more precise conclusions can be reached with respect to the evaluation of the characteristic being considered.

Every decision made in an organization is a function of the information the decision maker has at hand at the time of the decision. If a decision maker is lacking pertinent, relevant information, his decisions will reflect this.

It appears then, that there is a definite need for a technique which could analyze the information flow within an organization. Such a technique exists in the form of a simple matrix relation which identifies and traces data elements from their inclusion in source documents to the consolidated reports used by decision makers at various levels in the organization. Comparison of this final derived matrix with a reference matrix constructed with prior knowledge of the data elements needed for each decision rule enables the analyst to indicate excessive routing of information or the lack of relevant information in a system. In other words, redundancy and certain elements of responsiveness as discussed in the preceding section are analyzed in detail.

Homer [Ref. 34] improved upon this technique which was initially developed by Lieberman [Ref. 44]. The following is a description of Homer's model, slightly modified to apply to military management information systems.

B. THE MODEL

The model consists of a single matrix, M, which represents the entire management information system with respect to data elements, reports, and decision rules. The steps for forming the system matrix are as follows:

Step 1: A row is established for each data element and report in the system.

Step 2: A column is established for each report and decision factor in the system.

Step 3: The number 1 will be inserted in each cell to represent an item of data appearing in a report, one report used to produce another, or a report upon which a decision factor is based. An example of a decision factor might be man-days behind schedule. This factor, should it become too large would cause the manager to add more men to a shop or take other corrective action.

Step 4: Each report is represented by both a column and a row. Into each cell formed by the intersection of an identical row and column, the value -1 will be inserted.

Step 5: All other cells will be labeled zero.

An initial or preliminary analysis of the system matrix can now be made. First, any column which contains only zeroes should be removed. This indicates that a decision factor is not relevant to the system being considered or that no information is being reported upon which to base the decision and that a possible revision of the system is needed. A report column containing only zeroes indicates a clerical error.

Next, any row which contains only zeroes should be removed. This indicates that a data element is superfluous to the system being evaluated. Again, a row representing a report containing only zeroes indicates a clerical error.

If a column contains -1 as the only non-zero entry, the component represented by that column is an input to the system and the column

should be removed. If a row contains -1 as the only non-zero entry, the component represented by that row is an output of the system and the row should be removed.

Inputs and outputs of the system can now be identified. Any row not containing a -1 entry is an input. Similarly, any column not containing a -1 entry is an output. An output is normally a decision factor, but it may be a report or even a data element as the reader will observe in the application that follows this discussion. The solution area of the matrix consists of those cells formed by the intersection of input rows and output columns.

Once the solution area has been identified, the solution matrix, M*, to the system matrix is derived by performing elementary column operations only. The procedure is to perform the necessary elementary column operations to reduce to zero each entry in an output column other than those in the solution area. The resulting values in the solution area represent the number of ways in which each input "reaches" each output. The solution matrix, M*, is then subtracted from the reference matrix mentioned earlier, giving an indication of excessive routing of information or the lack of needed information at a particular level within the organization. For a detailed discussion and mathematical proof of this procedure, the reader is referred to Reference 34.

C. A MILITARY APPLICATION

In 1967, the Office of the Deputy Chief of Staff, Logistics, Department of the Army, contracted a civilian research firm to design an

integrated MIS. This MIS was to provide materiel readiness, supply, and maintenance information to Army managers at each echelon of command or logistics support level. The design did not include automatic data processing programming or specifications for data processing equipment. The design description did, however, permit the Army to proceed with programming and operating instructions without further systems development effort.

Generally, the designers of the proposed MIS claimed that their system would accomplish the below listed improvements:

Simplify and reduce reporting data elements

Consolidate major reporting systems

Improve data reliability

Improve responsiveness

Improve evaluation of operating elements

Simplify report formats

Diagnose potential management deficiencies

The modified Homer's matrix evaluation technique discussed above will be used to evaluate the results of the first two listed improvements. It is not this author's intention to rigidly analyze the proposed MIS. Such a task is infeasible due to the fact that the contractor's report is not specific enough to accurately define the relationships between source data elements, records and reports, and decision factors to be used. Instead, a small portion of the over-all system, maintenance performance evaluation at the depot level, will be extracted and examined.

Table II lists all the data elements required for depot level maintenance performance evaluation, a matrix code assignment for each element, and the reports that utilize each element.

Table III is a list of the ten reports required by the proposed system. All reports are independent from each other except Report r_2, Backlog Analysis by FSN, and Report r_7, Unwarranted Equipment Evacuations. Report r_2 is needed to produce Report r_4, Lack of Reparables. Report r_7 is used to produce r_8, Unwarranted Maintenance Evacuations-Detailed Listing.

The decision factors assumed to be used in maintenance performance evaluation are listed in Table IV. Also listed is the code assigned to each factor and the reports that compute each factor. These decision factors were extracted from the exhibits of depot maintenance reports listed in the contractor's project report. It is assumed that each of these computations is to be compared against some standard set by the manager, thus indicating to him satisfactory or unsatisfactory performance and the reasons therefore.

Utilizing Tables II-IV, the system matrix, M, can be constructed by following the five steps listed in the last section. Figure 5 is the resulting system matrix.

A preliminary analysis of the matrix indicates that reports r_9 and r_{10} are actually outputs of the system and the matrix rows corresponding to these reports are removed. The solution area is then identified. Figure 6 shows the system matrix after preliminary analysis and identification of the solution area.

Data Element	Code	Used in Reports:
Maintenance Organization Name	i_1	$r_1, r_3, r_4, r_5, r_6, r_9, r_{10}$
Master Schedule Item- No.	i_2	$r_1, r_2, r_3, r_4, r_5, r_9, r_{10}$
Master Schedule Item- FSN	i_3	$r_1, r_2, r_3, r_4, r_5, r_9, r_{10}$
Master Schedule Item- Noun	i_4	$r_1, r_2, r_3, r_4, r_5, r_9, r_{10}$
Work Stoppage Part- FSN	i_5	r_3
Work Stoppage Part- Name	i_6	r_3
Work Stoppage Part- Reqn No.	i_7	r_3
Program Qnty Required- Parts	i_8	r_3
Critical Qnty Required- Parts	i_9	r_3
Work Stoppage Date	i_{10}	r_3
Master Schedule Item- Critical Qnty	i_{11}	r_1, r_2, r_3
Quantity Scheduled	i_{12}	r_1, r_2, r_3, r_4, r_5
Quantity Completed- Per Month	i_{13}	r_1, r_2
Cause For Delay	i_{14}	r_1, r_2
Equip. Scheduled to be Turned In	i_{15}	r_4
Average Man-hours Programmed	i_{16}	r_1, r_5, r_6, r_7
Average Man-hours Expended	i_{17}	r_5
Man-hours Expended Code	i_{18}	r_6
Actual Man-hours Expended	i_{19}	r_6
Command Code	i_{20}	r_7, r_8
Qnty of Equipment Inspected	i_{21}	r_7
No. of Unwarranted Equip. Evacs	i_{22}	r_7
Est. Man-hours Required for Repair	i_{23}	r_1
FSN	i_{24}	r_8
Brief Nomenclature- FSN	i_{25}	r_8
Type- Model- Series	i_{26}	r_8
PCN	i_{27}	r_8
Initial Schedule Date	i_{28}	r_9, r_{10}
Part Shortage-FSN	i_{29}	r_{10}

TABLE II. Data Elements Required at the Depot Level

Data Element	Code	Used in Reports:
Part Shortage- Nomenclature	i_{30}	r_{10}
Part Shortage- Quantity	i_{31}	r_{10}
Requisition No. - Parts	i_{32}	r_{10}
Equipment Shortage- FSN	i_{33}	r_9
Equipment Shortage- Nomenclature	i_{34}	r_9
Quantity Short- Equipment	i_{35}	r_9
Document No. - Equipment	i_{36}	r_9
No. of Direct Labor Men/Work Center	i_{37}	r_1

TABLE II. (con't) Data Elements Required at the Depot Level

Reports Required by Proposed MIS	Code
Backlog Analysis - By Work Center	r_1
Backlog Analysis - By Federal Stock Number	r_2 *
Work Stoppage Items	r_3
Lack of Reparables	r_4
Man-hour Utilization	r_5
Assigned Time Analysis By Work Center	r_6
Unwarranted Equipment Evacuations	r_7
Unwarranted Maintenance Evacuations - Detailed Listing	r_8
Equipment Shortages	r_9
Parts Shortages	r_{10}

*-- Report used to produce another report.

TABLE III. Reports Required at the Depot Level

Decision Rules of Proposed MIS	Code	Reports Utilized
No. of Equipments Behind Schedule	d_1	r_1
% of Equipments Behind Schedule	d_2	r_1
Man-days Behind Schedule	d_3	r_1
Shop-days Behind Schedule	d_4	r_1
Cumulative Programmed Output/Item	d_5	r_1, r_2, r_4
Cause For Delay	d_6	r_1, r_2
Cumulative Actual Output/Item	d_7	r_2, r_4
Programmed:Actual Performance	d_8	r_5
Critical Stoppages	d_9	r_3
Assigned Time Index	d_{10}	r_6
Rate % Unwarranted Equipment Evacuations	d_{11}	r_7
Unwarranted Work Requests-Estimated Man hour	d_{12}	r_7
Unit Evacuation Performance	d_{13}	r_7, r_8

TABLE IV. Decision Factors Utilized at the Depot Level

FIGURE 5 The System Matrix

					r												d						
	01	02	03	04	05	06	07	08	09	10	01	02	03	04	05	06	07	08	09	10	11	12	13
01	1	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
02	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
03	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
04	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	1	0	0	0	C	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
15	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
i 19	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01	-1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0
02	0	-1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
03	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
04	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
r 05	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
06	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
07	0	0	0	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
08	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
09	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0

FIGURE 6 The Solution Area

					r												d						
	01	02	03	04	05	06	07	08	09	10	01	02	03	04	05	06	07	08	09	10	11	12	13
01	1	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
02	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
03	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
04	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
15	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
i 19	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01	-1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0
02	0	-1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
03	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
r 04	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
05	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
06	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
07	0	0	0	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
08	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Note: The solution area is enclosed in the rectangle above.

FIGURE 7 The Final Matrix

						r												d						
		01	02	03	04	05	06	07	08	09	10	01	02	03	04	05	06	07	08	09	10	11	12	13
	01	1	0	1	1	1	1	0	0	1	1	1	1	1	1	2	1	1	1	1	1	0	0	0
	02	1	1	1	1	1	0	0	0	1	1	1	1	1	1	4	2	3	1	1	0	0	0	0
	03	1	1	1	1	1	0	0	0	1	1	1	1	1	1	4	2	3	1	1	0	0	0	0
	04	1	1	1	1	1	0	0	0	1	1	1	1	1	1	4	2	3	1	1	0	0	0	0
	05	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	06	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	07	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	08	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	09	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	11	1	1	1	0	0	0	0	0	0	0	1	1	1	1	3	2	2	0	1	0	0	0	0
	12	1	1	1	1	1	0	0	0	0	0	1	1	1	1	4	2	3	1	1	0	0	0	0
	13	1	1	0	0	0	0	0	0	0	0	1	1	1	1	3	2	2	0	0	0	0	0	0
	14	1	1	0	0	0	0	0	0	0	0	1	1	1	1	3	3	2	0	0	0	0	0	0
	15	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
	16	1	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	0	1	0	1	1	1	2
	17	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	18	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
i	19	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	20	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	21	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
	22	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
	23	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	25	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	26	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	27	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	28	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	31	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	32	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	33	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	35	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	36	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	37	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0
	01	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	02	0	-1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	03	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	04	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
r	05	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	06	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	07	0	0	0	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	08	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 7 shows the system matrix, M*, after the necessary column operations have reduced to zero each entry in an output column other than those in the solution area. Notice that some inputs reach the decision factors in more than one way. If, after subtracting M* from the reference matrix, there resulted negative values in the solution area, excessive routing of information might be indicated and revision of the reporting system would then be necessary. If positive values resulted in the solution area, it might indicate a lack of the information desired to compute a decision rule and again, a revision of the reporting system would be needed.

For example, suppose that the decision maker desired that each input flow through the organization in such a manner as to reach its relevant decision factors from two different sources. A glance at Figure 7 shows that source data element i_2, Master Schedule Item-No, progressed through the system and ultimately was utilized by decision factor d_5, Cumulative Programmed Output/Item, from four separate reports. In this case, the system is redundant. Another glance at Figure 7, this time scanning row i_{23}, indicates another need for a system revision. This time data element i_{23} needs to be added to other reports as it is currently being utilized from only one report by each of its relevant decision factors.

D. CONCLUSIONS

The Homer model for analyzing the flow of information can be a valuable tool for the analyst for determining excessive routing of

information or the lack of required information. The technique is dependent upon the analyst's ability to identify all the individual components of an information system and the ability to establish a reference matrix against which to compare the derived solution matrix.

The latter requirement provides the major obstacle to maximum utility of the model. It is a recognized difficult task to identify all the decision rules in a complex organization and it is even more difficult to identify the multitudinous parameters relating to these decision rules. Hence, the reference matrix may be, in reality, impossible to obtain. Even if this were so, the preliminary analysis made on the system matrix is extremely useful due to the fact that extraneous data elements and non-relevant decision factors are identified.

The model provides several advantages to the analyst in addition to presenting a complex organization in relatively simple form. First, it becomes easy to divide systems analysis work amongst the members of an analysis group due to the nature of the system matrix. Secondly, the model lends itself very well to the computer. Another advantage is the experimentation that can be carried on with the model to determine the effects of system change without disturbing the actual system. Lastly, the informal communications system of an organization may be incorporated into the model, thus allowing the analyst to evaluate this important segment of an information system and compare it to the formal structure. [Ref. 37]

IV. RECOMMENDATIONS

It is anticipated that two separate groups of people will be able to use this thesis to their advantage -- military managers and operations research analysts. This section of the paper offers recommendations to these people as to how they may possibly use this thesis.

There has been much effort to date to find ways to measure the technical aspects of management information systems. The overall measurement of the entire system from a manager's viewpoint has practically been ignored. It is hoped that the military manager will find the techniques discussed in this thesis useful in measuring the effectiveness of his system. At the least, this thesis should alert military mangers that techniques are available and that future efforts to expand these techniques are worthwhile with respect to improving the processing of management information in the military. The author recommends that interested managers apply the techniques discussed in this paper to their existing MIS to determine if, in fact, the results support his intuition and military judgement of the system or perhaps even identify weaknesses he had not previously considered.

In viewing this thesis as a stage in a research continuum, there are several logical follow-on studies. First, this author has identified what he believes to be a set of characteristics common to all management information systems. It is recommended that these characteristics be tested and verified through empirical studies. The author suggests that the semantic differential could well be used as a technique to

accomplish this. By polling known experts in the field of MIS design and experienced users of MIS's, the differential would establish the acceptability of these characteristics. Secondly, the techniques themselves should be verified. In other words, do the techniques result in accurate measures of a system being considered? This is not an easy task. This author recommends that the Semantic Differential and Homer's input-output model should be applied to evaluate a system with known defects. If the techniques detect and measure these defects, it would indicate that they are valid. Finally, the author hopes that by discussing a few of the techniques available, other researchers will contribute more techniques, thus expanding the tools the manager can use to measure the effectiveness of his system.

V. SUMMARY

To date, there has been little consideration of the military manager's desire to analyze his management information system from a managerial viewpoint. Most of the evaluative techniques developed have been used to analyze the technical aspects of a system such as file organization, coding and decoding, and retrieval and transmitting procedures. The military manager has been left to use his intuition and experience to satisfy his analysis needs.

This thesis has been a first step toward satisfying the military manager's needs in this area. It presented two operation research techniques that the manager could use to scientifically evaluate a MIS

and suggested that many more procedures exist. The first approach discussed, the semantic differential, considered the system as a whole; qualitatively evaluated it with respect to a set of characteristics common to well designed MIS's; and then converted these qualitative measurements to quantitative measurements to allow comparison with other systems. Thus, this technique was a combination of controlled association and sealing procedures which provided two separate analyzes: (a) the identification of strong and weak characteristics of a system and, (b) a scalar rating factor which, when properly used, allowed a comparison of similar systems.

In order to use this technique, it was necessary to define the characteristics of a well designed MIS. After a rather comprehensive literature search, the author developed the below listed set of characteristics which could be used as a framework for the evaluation of a system regardless of the evaluation technique used.

1. Structure of the data base
2. Characteristics of Information
    a. Accuracy
    b. Quantity
    c. Relevance
    d. Simplicity
    e. Timeliness
    f. Compatibility
    g. Quality

3. Type of System-Manual or Computer-based?

4. Long and Short-range Perspectives of the System

5. Responsiveness

6. Flexibility

7. Acceptability

8. Redundancy

These characteristics served as standards against which to compare the characteristics of the MIS being evaluated. The strength of the semantic differential is a function of the quality of these standards and the statistical procedures used in the evaluation.

The second approach discussed was typical of the many techniques available which could be used to measure more definitively a specific characteristic of the system, e. g. a weak area identified by use of the semantic differential. This technique, an input-output model of an information system developed by E. D. Homer, traced the flow of information throughout the system without regard to an organizational structure. As a result, excessive routing of information and the lack of required information upon which to compute decision rules were detected. In order to apply the technique, a manager needed only to know simple matrix operation procedures. The major disadvantage of this technique was that one assumed that information requirements and decision factors were known. Experience indicates that this is not always the case. The main advantage of this technique was that it enabled the analyst to model a complex system in simple form.

In conclusion, it has been demonstrated that there is a methodology for evaluating management information systems from a managerial viewpoint. Using operations research techniques, the military manager can combine his experience and judgement with scientific procedures to evaluate complex procedures. He can evaluate the system as a whole using a technique such as the semantic differential or he may choose to analyze a small portion of the system by using one of the many procedures known to the operations analyst today. The problem of analyzing unquantifiable systems is formidable, but a solution is attainable with operations research techniques.

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13. ABSTRACT

To date, little progress has been made toward the establishment of scientific procedures by which a military manager can evaluate complex cybernetic systems such as management information systems.

To provide a methodology yielding quantitative results which may assist a commander and his staff in this analysis, it is proposed that management information systems be evaluated as a whole by a technique defined as the semantic differential. Each characteristic of the system evaluated is compared to a standard or reference characteristic desired in a well designed system and a value is assigned based on the closeness of the comparison.

A second, more detailed, approach is also considered. This technique detects redundancy and lack of responsiveness in a system by means of a matrix model of the system. Using input-output analysis on the model, it is possible to determine excessive routing of information and lack of the necessary information to compute decision rules.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Management						
Management Information Systems						
Information System Evaluation						
Operation Research Techniques						
Management Science Techniques						
Semantic Differential						
Input-Output Analysis						

Thesis
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The application of operations research techniques to the evaluation of military management information systems.